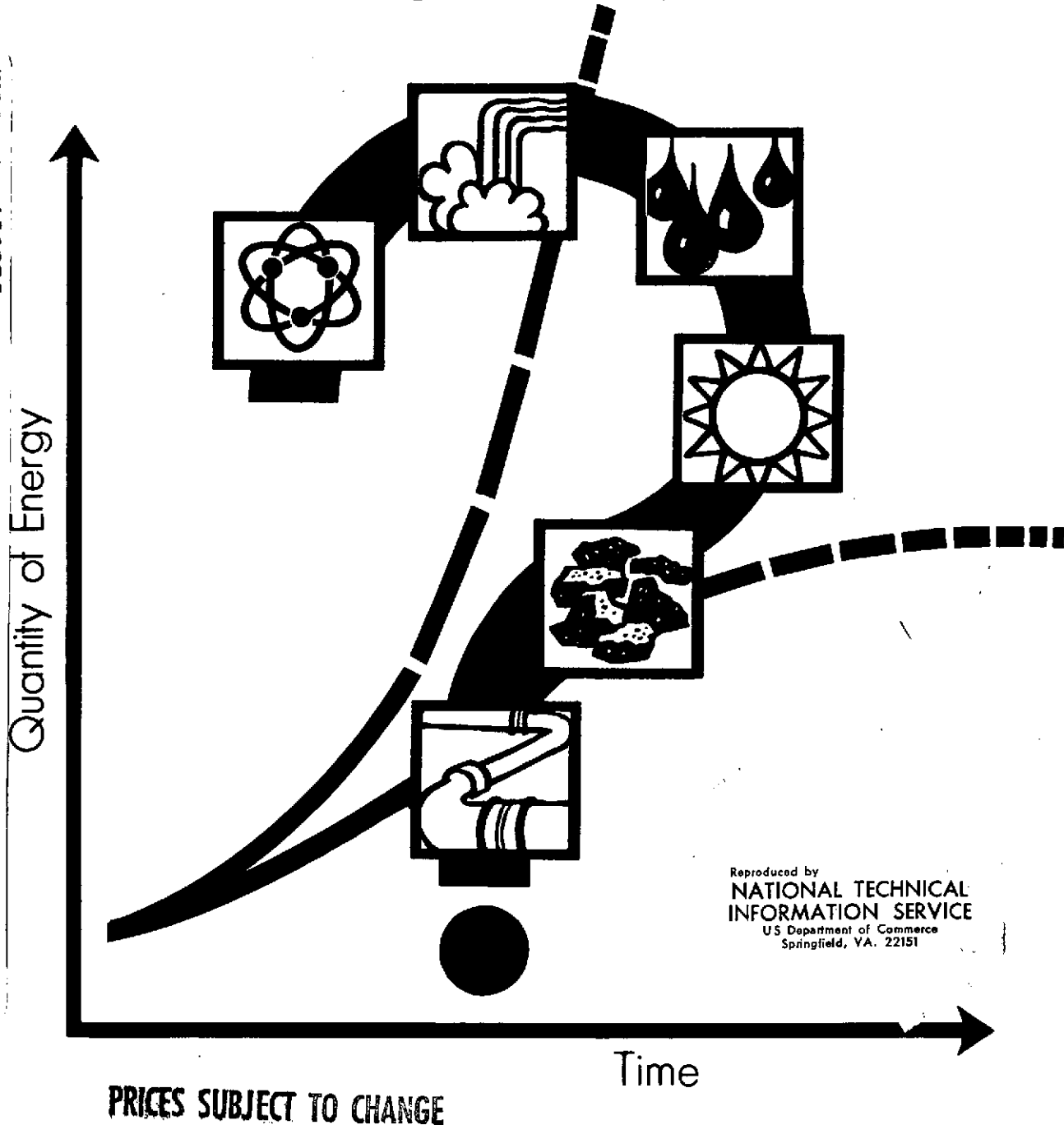


# MEGASTAR

The Meaning of Energy Growth: an Assessment of Systems, Technologies, And Requirements



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# MEGASTAR

## The Meaning of Energy Growth: An Assessment of Systems, Technologies And Requirements

by

AUBURN UNIVERSITY ENGINEERING SYSTEMS DESIGN

SUMMER FACULTY FELLOWS

### EXECUTIVE SUMMARY

Prepared Under

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SEPTEMBER, 1974

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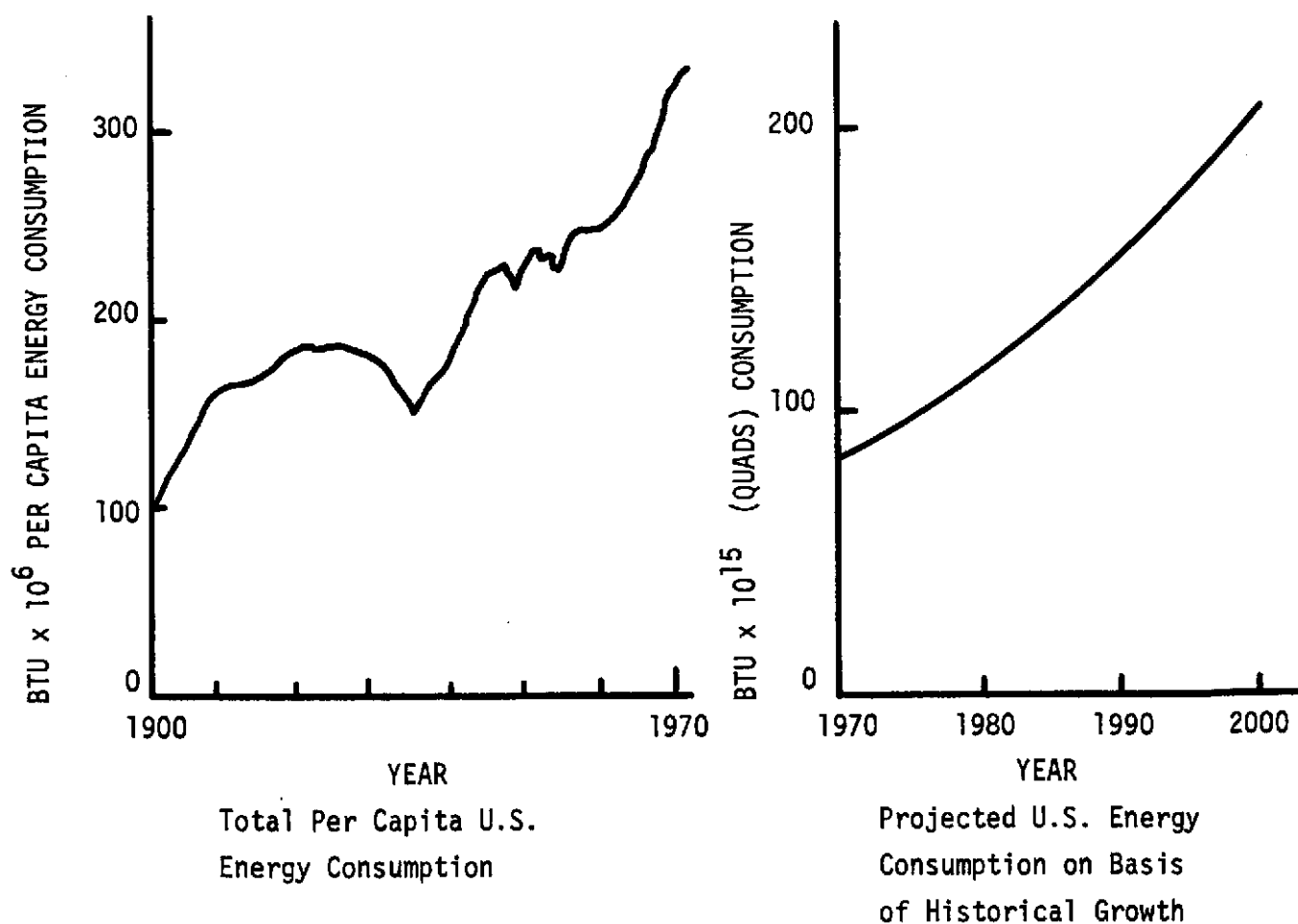
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## 1. INTRODUCTION

MEGASTAR presents a methodology for the display and analysis of postulated energy futures for the United States. A systems approach methodology including the methodology of technology assessment is used to examine three energy scenarios--the Westinghouse Nuclear Electric Economy, the Ford Technical Fix Base Case and a MEGASTAR generated Alternate to the Ford Technical Fix Base Case. The three scenarios represent different paths of energy consumption from the present to the year 2000. Associated with these paths are various mixes of fuels, conversion, distribution, conservation and end-use technologies. MEGASTAR presents the estimated times and unit requirements to supply the fuels, conversion and distribution systems for the postulated end uses for the three scenarios and then estimates the aggregate manpower, materials, and capital requirements needed to develop the energy system described by the particular scenario. The total requirements and the energy subsystems for each scenario are assessed for their primary impacts in the areas of society, the environment, technology and the economy. MEGASTAR suggests areas for detailed study and raises issues for discussion.

## 2. THE U.S. ENERGY PROBLEM

It is clear that the U.S. has had an energy problem during the 1973-1974 period due to the imbalance between shortages in supply and increasing demand. The history and projection of energy growth on the basis of historical patterns as seen below suggests what U.S. energy consumption may be in the future and also suggests that shortages may become prevalent when compared to resources without a new energy policy. It is not clear what future energy policy should be. One of the prerequisites of any policy development is the availability of reliable information and the display of this information understandable by all who must participate in solving the problem.



The energy problem in the U.S. is multifacted and cannot be stated in a concise form representing every viewpoint.

To the business owner it may be rising prices for the fuel and electricity he uses.

To the motorist it may be uncertainty regarding gasoline availability on a Sunday during his vacation in another state.

To the economist it may be concern about international prices and markets and multinational corporate, monopoly or cartel control of the market.

To the politician it may be an uncomfortable alliance brought about by dependence on the resources of another country.

To the scientist or engineer it may be an opportunity to develop new technology for providing energy systems and end use devices.

To the utility industry it is new problems in finding capital, power plant sites, generating equipment, transmission right-of-way and equipment, and manpower to meet the historically projected demand of a growing nation with a tight money supply.

To the energy industry it is a challenge to meet present demand and to prepare to meet future fuel demands that are uncertain as to form as well as quantity.

To everyone it is increasing prices and fear about the availability of electric power, heating fuel, transportation fuel and ultimately his life style.

In short it is a dilemma to the individual and to the nation, it is a dilemma that must be resolved. Furthermore, the dilemma embodies energy resources, energy generation and conversion systems, distribution of energy, conservation of energy and the many end uses of energy. The dilemma is interrelated to other aspects of society and hence has political, social, economical, environmental and cultural dimensions.

### 3. THE U.S. ENERGY DILEMMA

Some aspects of the U.S. energy dilemma:

- ° U.S. energy consumption is growing exponentially. The current U.S. consumption of 70 quads per year is projected on the basis of historical growth to be approximately 200 quads per year by the year 2000.
- ° There is rapid growth in consumption and declining production of oil and gas resulting in rapid growth in dependence on costly and unreliable foreign sources.
- ° There is considerable uncertainty regarding domestic oil and gas resources.
- ° There is a large array of possible options and few clear guidelines for choosing among them.
- ° It is not clear how to implement the chosen options, i.e. how to plan one sector of an unplanned economy.

The most important thing to emphasize is that none of the elements of the energy dilemma have disappeared. The "energy crisis" may be over, but the dilemma remains.

### 4. THE NEED FOR A U.S. ENERGY POLICY

The dilemma and the effect of the Arab oil boycott suggests the need for a U.S. energy policy to assure the reliability of future energy sources. The need is now compounded because of the expectation of a new policy and the uncertainty as to what the policy will be. As a result, there is considerable justifiable pressure to formulate a general energy policy as rapidly as possible. At the same time energy supply has sufficient importance for economic stability to require a rational, well-founded policy. There is a requirement for sufficient time to determine alternatives, carefully assess their requirements and consequences, extract from the process a satisfactory policy, and determine the best means for implementation. MEGASTAR presents a method for assessing alternative energy futures and examines three energy futures for the U.S. The study was intended primarily as an aid to decision makers at all levels of government and industry. It is also hoped that citizens will make use of the information in this and other reports to inform themselves of the feasible energy policy alternatives open to our society. Two other major studies are to be completed that compliment MEGASTAR--The Ford Report of the Ford Foundation Energy Policy Project and the Project Independence Blueprint. Both these studies plus MEGASTAR and studies cited in MEGASTAR should provide substance for debate of the issues. Advanced Reports [SAULTER-74] indicate the final conclusion of the Ford Energy Policy Project will be to recommend an energy scenario in which the nation achieves



zero energy growth by the year 2000. Project Independence has as its initial objective reducing the dependence of the U.S. on foreign imports. The decision as to policy has not been made but the nation must face the issue and understand the impacts of the policy adopted. As will be pointed out, one must bear in mind that energy is but one requirement for a viable nation and decision regarding energy must be in harmony with the other requirements of our nation.

## 5. METHODOLOGY FOR ASSESSING ENERGY FUTURES

A systems approach coupled with the methodology of technology assessment was used to define an objective to delineate the energy dilemma into a tractable problem and to assure the examination of the problem in its total environment. The general objective was to assess energy systems, technologies, and requirements in order to understand the meaning of energy growth a priori. The MEGASTAR result consists of:

- ° A methodology for assessing energy growth.
- ° Three illustrative assessments.
- ° Insights into the energy dilemma.

There are many considerations between the objective and the result. The considerations leading to the MEGASTAR result include:

- ° Establishing a data base on energy resources, conversion and generation systems, distribution systems and end uses.
- ° Defining energy futures.
- ° Describing alternate paths to each energy future.
- ° Determining the requirements--manpower, money and materials for each path.
- ° Evaluating the impacts of the requirements for each path on the technical, social, cultural, political and economic sectors of our nation.
- ° Displaying the result.

The considerations indicated are examined as follows:

### ° Data Base

The data base on energy resources, generation/conversion distribution and utilization included documents as well as consultants. The affiliations of the consultants are as follows:

Public Sector	51	Private Sector	87
Federal Gov't	31	Corporations	76
State Gov't	3	Institutes, Assoc.	11
Universities	16		
Foreign Gov't	1		

The 418 page appendix of MEGASTAR constitutes a distillation of the information processed.

### °Energy Futures

An energy future consists of the specification of the principal energy forms and relative amounts of each needed to achieve a certain gross energy consumption. Sufficient detail of the population mix is required to determine compatibility with the energy consumption requirements. GNP mix is needed to determine if disproportionate shares of the GNP are being used by the energy industry. The competition mix within the energy industry yields a picture of the reasonableness of the energy mix. Finally, the conservation mix determines demands on consumers and technology implied in the energy future.

### °Alternate Paths

There are a large number of alternate paths between the present and any future point. The problem is to reduce the number to a few that are tractable for analysis. In the case of energy futures the number of paths can be greatly reduced by the requirements of continuity and smoothness. This, however, is not enough to ensure that the path is viable. Variations in parameters such as fuel mix, economic constraints, and other social factors must be considered. In the case where the path calls for the growth of a new technology the existence of a base upon which that growth can take place must be investigated. Once all of these factors have been considered there are usually only a few viable alternatives left for analysis. The three paths considered in MEGASTAR are embodied in the three scenarios:

Westinghouse Nuclear Electric Economy  
 Ford Technical Fix Base Case  
 MEGASTAR Alternate to Ford Technical Fix Base Case

### °Requirements

Once the paths were defined in terms of total consumption and fuel mix, these definitions were translated into numbers of power plants, oil wells, mines, etc. Unit requirements were determined for all the constituents of the particular path. For example, the capital manpower and materials necessary to build a 1000 MW<sub>e</sub> nuclear power plant or to open a new 2,000,000 Ton per year coal mine. Once the number of facilities of each type is known for a given path, it is easy to sum up the necessary individual units to give the total capital, manpower and material requirements for the path. This assumes, of course that the unit selected is typical (average).

It is, however, often of interest to look beyond the gross totals to try to uncover bottlenecks. For example, it has been found that in some instances the barrier to opening a new strip mine is the lack of draglines. Moreover, dragline production is already committed for three years in advance. Thus, even though the capital manpower and other materials are available it would take four to five years to start a new strip mine that uses a dragline because of the bottleneck in dragline production. A recognition of the manpower, materials, and money bottlenecks does give an indication of the difficulty in meeting the requirements of a given path. The purpose of determining the path requirements is to be able to understand the total social commitment necessary to follow the indicated path.

### °Impacts of Requirements

Once the requirements are known for a given path of action, the next step is to elucidate and evaluate the technical, environmental, economic, social and political impacts of those requirements.

Examples of selected impact areas in various categories are as follows:

#### Technical Impact Areas

- Design facilities
- General production facilities
- Capacity to produce scarce equipment
- Technical manpower utilization

#### Environmental Impact Areas

- Air quality
- Water quality
- Water use
- Land use
- Sound levels
- Biological activity
- Solid waste production
- Thermal pollution levels
- Radioactivity levels

#### Economic Impact Areas

- Demand for capital
- Wages
- Inflation
- Price of energy
- GNP

#### Social/Political Impact

- Housing
- Schools
- Roads
- Fire/Police protection
- Sewers
- Sewage treatment
- Public transportation
- Training
- Government
- Other institutions
- Individual freedom
- Government regulation
- Life-styles
- Standard of living

In MEGASTAR the emphasis is placed on uncovering the impacts and their magnitudes rather than attempting to make value judgments about them.

### °Displaying the Result

MEGASTAR and this executive summary constitute two displays of the study.

## 6. ENERGY SCENARIOS - ENERGY FUTURES & PATHS

### °Scenarios

There are a number of energy scenarios that constitute an energy future and a path. Some include:

Department of Interior [Dupree 72]  
 Joint Committee on Atomic Energy [JCAE-74]  
 Atomic Energy Commission [EPO-74]  
 National Academy of Engineering [NAE-74]  
 Environmental Protection Agency [EPA-73]  
 Shell [Shell-73]  
 National Petroleum Council [NPC-72]  
 Council on Environmental Quality [CEQ-74]  
 Nuclear Electric Economy (NEE) [Ross-73, Cregan-74]  
 Ford (FTFB) [Ford-74]

MEGASTAR selected the last two to demonstrate the examination of energy growth a priori on the basis of the following criteria.

Politically and industrially well-known, popular, and judged likely to occur;

Energy and slope predicted at the year 2000 (the next ten years are nearly fixed . . . beyond 2000 would be too speculative);

Source and use mix proposed and documented;

A suggested implementation plan that includes technical fixes (conservation through efficiency using present technology);

Present economic impetus maintained;

Needed industrial skills available;

Near energy independence; and

Limited to the U.S.

These criteria were not judged to lead to the best energy future for the greatest good of all. They were judged to be either necessary to assess a future, or necessary to be credible to most people in decision-making positions.

### °NEE & FTFB Overview

The NEE, the FTFB, and a baseline future for the year 2000 (what 2000 would be if we made no change) are displayed and compared with the present [Ford-74] and with the AEC's Dixy Lee Ray 1980 and 1985 projections [EPO-74]

in Table I. For 1972 coal (11 Quads), oil (33 Quads) and gas (23 Quads) make up 15 percent, 46 percent and 32 percent of the source mix respectively. This compares with 32 percent, 43 percent and 21 percent for the world's consumption [Felix-72]. Total world consumption is triple that of the United States. Table I shows that the high oil and gas and high coal consumption continues at the year 2000 for the baseline. They are reduced in percentage because nuclear's 54 Quads comprise 27 percent of the total. It is important to recognize that this baseline projection is close to what three different scenarios predict if the U.S. makes no national effort to change anything.

The post-embargo [EP0-74] 1980 and 1985 projections show a lower oil consumption than the baseline because the initial statement of Project Independence arbitrarily set oil imports at zero. If gas consumption does not increase, domestic oil would have to increase in order to equal the total of 56 quads shown in Table I by 1985 for oil and gas. The total quads in 1985 shown in Table I are lower in EP0-74 relative to DOI because of the conservation effort that is part of the Dixy Lee Ray scenario.

TABLE I COMPARISON OF ENERGY QUADS FOR TWO FUTURES PLUS BASELINE

	1972	Baseline <sup>a</sup>			EPO-74 1980	EPO-74 1985	NEE <sup>c</sup> 2000	FTFB	
		DOI 1980	DOI 1985	2000				1985	2000
Total Quads	72	96	117	200	89	105	207	95	120
Energy/yr.	4%			4%			4%		1.7%
Pop./yr.	1.5%			1.5%			1.5%		.6%
Coal, Direct	11	16	21	38	} 20	} 29	39	18	25
Coal, Syn. Fuel							14	2	6
Oil, Dom.	23	} 42	} 51	} 102	46.5 <sup>d</sup>	} 56	20	25	36
Oil, Imp.	10				12.5		2	1	0
Gas, Dom.	21	} 27	} 28	}		} 0	9	32	28.5
Gas, Imp.	2						0		4
Nuclear	2	7	12	54	8	16	94	12	18.5
Hydro, etc.	3	4	4	6	3	4	16	5	7
Conservation					(10) <sup>b</sup>	(15) <sup>b</sup>			
Residential	12			18			13		11
Commercial	9			20			15		13
Transportation	18			45			24		24
Industry	20			54			40		38
Processing	13			64			115		34

a) Pre-embargo DOI [Dupree-72] projections were used for 1980 and 1985. For 2000 an average of DOI and post-embargo NEE base [Ross-73] and Ford historical [Ford-74] was used. Post-embargo differs in that oil and gas are down 5%, coal up 4%, and nuclear up 1%.

b) Must be added to total quads if savings not achieved.

c) Energy consumed in generating electricity for 1972 is 18 quads out of 72 total (25%), for the NEE base . . . 96/207 (46%), and for the NEE itself . . . 150/296 (72%).

d) The 46.5, includes gas, dom. and gas, imp., but not oil imp.

## °NEE

The NEE has built into it an historical 4 percent energy growth rate that assumes a 1.5 percent population growth rate [U.S. Census-72, Series C] prior to 1985 and a zero population growth rate (Series F) from 1985 to 2000 [Dunning-74-1]. The nuclear electric economy is characterized at the year 2000 by:

- A large continuing energy growth rate;
- A high nuclear energy consumption of 94 Quads;
- A high coal consumption;
- Oil consumption that is less than at present; and
- A much lower gas consumption than at present.

If Project Independence stimulates a rise in domestic oil and gas production by 1985 then NEE must predict domestic oil and gas peaking between 1985 and 1990 before dropping to their total 31 Quads by the year 2000.

Notice in Table I the high processing loss in the NEE that is inherent in any electric economy. A total of 115 Quads are lost for 92 Quads of end use in the residential, commercial, transportation, and industrial sectors. Part of the NEE scenario is to bring the breeder on-line. The 94 Quads of nuclear include 32 from the LMFBFR (liquid metal fast breeder reactor) and 8 from the HTGR (high temperature gas reactor). The NEE is truly an electric economy. Forty of the coal Quads (10 synthetic gas), 2 of the oil, and all of the "others" category, in addition to all of the nuclear are used to generate electricity. Major transformations to electric cars, heat pumps, waste heat use to generate electricity, and substitution of electricity wherever possible, would have to be made in manufacturing and end use. Westinghouse [Trumbower-74, Ross-73-1] projects:

	Space Heating						Electrical			
	Residential		Commercial	Commercial			Transportation			
	Heat Pumps	Elect. Resis.	Solar	Heat Pumps	Elect. Resis.		Cars	Busses	Trucks	Rail
	10 <sup>6</sup>	Homes		% of Sector						
1985	6	20		15	48	5 x 10 <sup>6</sup>	50% Urban 100% School	70% of Local		30%
2000	30	45	10	30	35	100 x 10 <sup>6</sup>				

Savings from technical fixes are shown in Table II.

The "others" category is unspecified. Hydro cannot provide more than 6 Quads. It is tempting to assign the remainder to solar plus geothermal. If NASA's program [NSF/NASA-72] were followed, solar would have this capability. [Dunning-74-1] favors additional nuclear use.

TABLE II A COMPARISON OF NEE AND FTF FIXES

Savings, in Quads for the year 2000

End Use Sector	Technical Fix	Heat Pumps, Process Heat, Process Steam	Better Constr.	Furnace/AC. eff.	Solar Htg. & Cool.	Total Energy Systems (MIUS)	Elec. Cars	Smaller Cars	Aircraft, Etc.	Transfer To Rail	Decrease Energy Intensive-ness	Metal Recycling	Other	Total
FTF Comm. and Resid.		5.4	4.2	1.5	1.5	.8 <sup>a</sup>							3.6	17
FTF Trans. <sup>b</sup>								9.3	2.8	4.1			1.8	18
FTF Industry		13.5									3.8	1.9	5.8	25
FTF, Not Above														5
<b>TOTAL</b>		<b>18.9</b>											<b>11.2</b>	<b>65<sup>c</sup></b>
NEE Comm.		4						1 <sup>d</sup>		1 <sup>d</sup>				6
NEE Resid.		4											1	4
NEE Trans.							8			15				23
NEE Industry		2											5	7
<b>TOTAL</b>		<b>10</b>								<b>16</b>			<b>6</b>	<b>40</b>

a) At 30-35% accounts for 2.7 quads or 10-12 x 10<sup>6</sup> people.

b) No electric cars; no mass transit.

c) By 1985, 19 quads.

d) Road oil and asphalt.



## °FTFB

Ford's historical growth postulates 185 Quads instead of the 207 Quads projected by NEE. This is a consequence of a 3.4 percent energy growth rate instead of 4 percent (average since 1950 rather than since 1965). TERRASTAR-73 points out that the 4 percent growth rate reflects the Vietnam War situation. It is hard to know what an optimum peace-time energy growth rate might be. The FTFB suggests the same end use of energy as does historical growth, but asserts that 185 Quads can be cut to 120 Quads by technical fixes, i.e., improvements in end use efficiency of energy. These are listed and compared with those from NEE in Table II.

In addition, FTFB is characterized by high oil and gas consumption, nuclear close to AEC's [EPO-74] for 1985, and coal at a level comparable to the baseline. Oil and gas resources are traded off for minimal risk to the environment from coal and nuclear reactors and their waste. The FTFB would require new technology to come on line by 2000 to maintain the conservation ethic or the energy growth rate would climb again. FTFB does not change the consumer's end use of energy, only the efficiency with which energy is consumed. No curbing of the "growth is good" ethic is hinted at. After the year 2000 energy growth would parallel historical growth once again. If this were taken literally, lead times would require planning in the 1990-2000 decade. Such planning was not taken into account in MEGASTAR.

## °MEGASTAR Alternate to Ford Technical Fix Base Case

MEGASTAR develops an alternate to the FTFB. The rationale for this alternate is as follows. The NEE was taken as an embodiment of a historical energy growth forecast. The FTFB was taken as an embodiment of an intermediate growth forecast. The two futures are remarkably similar in features other than energy. The FTFB has a historical growth economy in terms of quality of home life, travel and mobility, and size and distribution of GNP. Thus, within the meaning used herein of alternate paths, the FTFB is an alternate to the specific historical growth scenario, NEE. The two scenarios as given by their authors display alternate energy use levels, alternate growth rates, and alternate fuel mix. The two futures are alike in economic, social and political dimensions. The FTFB is historical in most things except the historical connection between economic growth and energy consumption. Thus an alternate path was developed to the FTFB. The specific feature of the FTFB scenario which was altered was the rate of energy growth at the year 2000. The feature of growth which is generally avoided in other scenarios is the point of change of slope on the "S" Curve" of consumption of a finite resource. Considerations of levels to growth lead naturally to scenarios of slow or zero growth. Thus, the alternative proposal for the FTFB case was one in which the growth of energy use reaches zero in the year 2000.

The three paths seen in Figure 1 while defined for two different energy consumption levels in the year 2000 are a set of linked alternates. The AFTB permits the U.S. to arrive at the year 2000 with options open and permits elevation of what the requirements and impacts are when pursuing a zero energy growth goal.

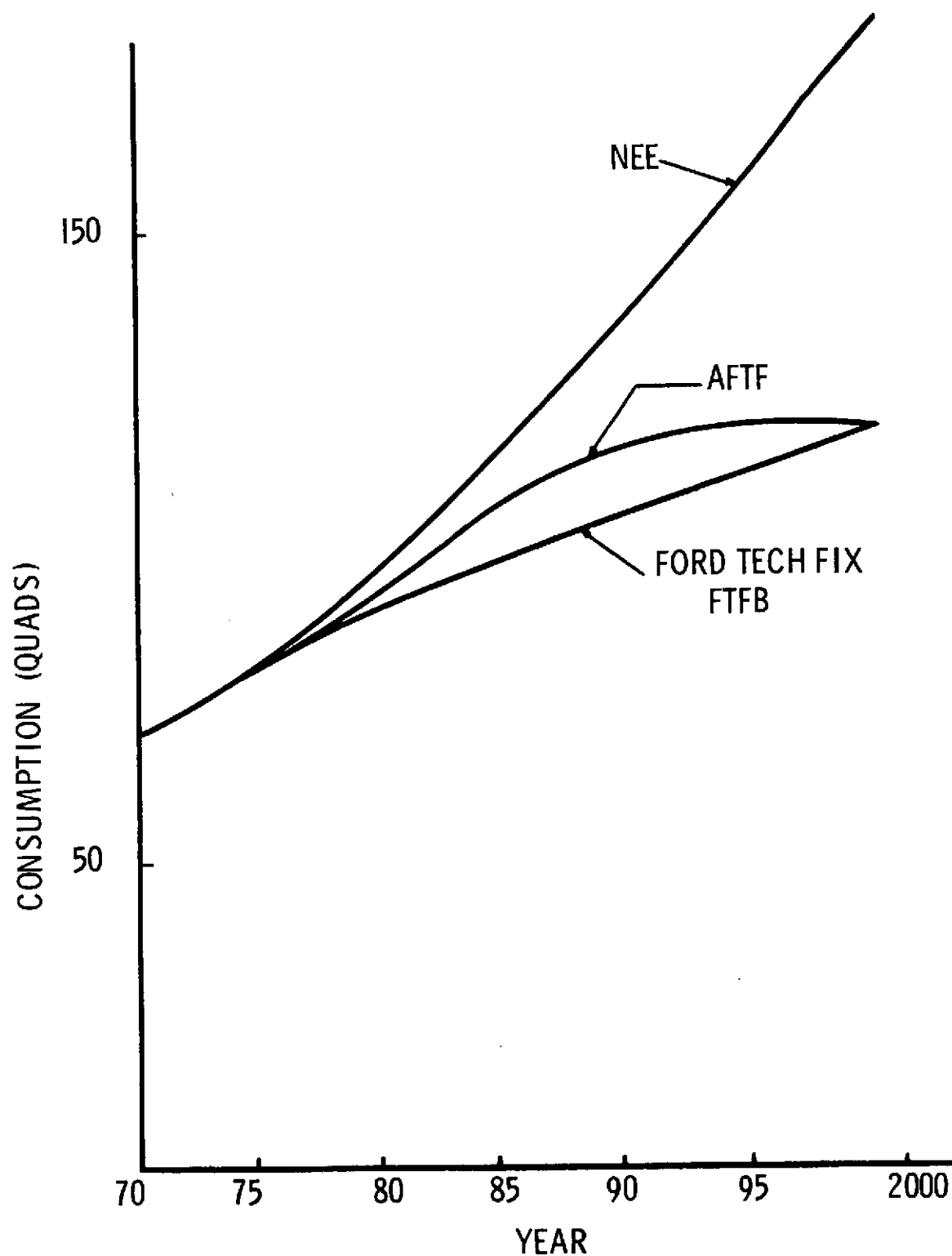


FIGURE 1 TOTAL ENERGY CONSUMPTION FOR THE THREE SCENARIOS.

NEE [Ross-73]. FTFB [Ford-74]. AFTF [Megastar-74].

THIS IS GROSS ENERGY CONSUMPTION INCLUDING CONVERSION LOSS.

## 7. REQUIREMENTS & IMPACTS FOR THE NEE, FTAB & AFTF

The manpower materials and money requirements and implied impacts for the scenarios are summarized as follows: The first order impacts of the requirements and the requirements are discussed in detail in MEGASTAR.

### °Manpower

The engineering manpower requirements for the three scenarios are shown in Figure 2. By the year 2000, the NEE path requires 2.8 times the engineers needed to support the FTFB path and 2.4 times the engineers to support the AFTF path. The AFTF requirement for engineers is always greater than that for FTFB for any year, reflecting the need for increased engineering effort in AFTF to overbuild the energy supply system in order to obtain zero energy growth at 2000. Both FTFB and AFTF require engineers to effect conservation measures.

In 1973, 105,000 engineers were employed in the energy sector and 1,200,000 engineers were in the U.S. workforce. Using the ratio ( $105,000/1,200,000 = 0.0875$ ) and the projection that 2,000,000 engineers will be in the U.S. workforce at 2000, 175,000 engineers are projected to be available in the energy sector at 2000.

The manpower condition is a severe one for the NEE, which requires 331,000 engineers (17% of all engineers) at 2000. Either engineers must be attracted into the energy sector from the total engineering population or a substantially larger number of engineering students must be graduated from engineering colleges than is anticipated. Engineering as a career must be made more attractive if the NEE is to be effected.

It appears that the projected engineering manpower figure of 175,000 (9% of all engineers) can support the engineering needs for FTFB and AFTF through the 2000. The implication is that a surplus of engineers for these two scenarios is possible; however, the employment conditions for engineers between now and 2000 will probably keep the energy sector needs and supply in balance, especially if the conservation ethic is pursued.

Non-engineering manpower requirements present a similar picture. Since the supplies of energy sector related skilled labor were not assessed they are not summarized here. There may be some supply problems in skilled labor, which should be assessed.

### °Materials Requirements

Figure 3 shows the steel requirements for the three scenarios. Generally, the AFTF and FTFB requirements are greater than those of NEE, reflecting the heavy reliance of the two scenarios upon gas and oil. Steel is required to carry out oil and gas exploration and development. The "kink" in the FTFB at 1990 comes from a drop in the need for gas and oil pipelines and tanker steel. This drop overrides the most significant steel requirement component, oil and gas exploration and development.

About 10 percent of U.S. steel production is utilized by the energy sector. During 1973, 150.8 million tons of raw steel, including 111.4 million tons of mill products, were produced in the U.S. Projections to

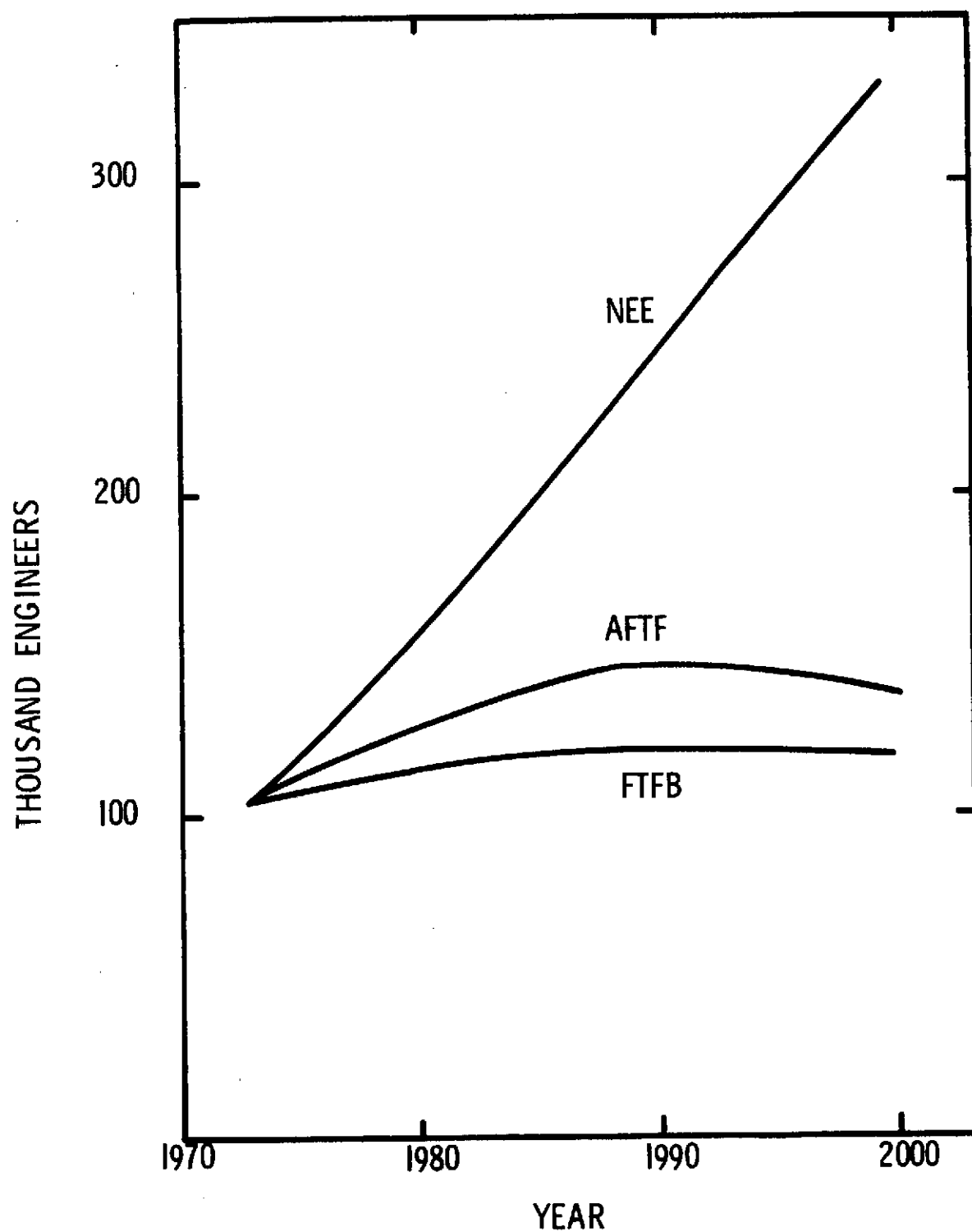


FIGURE 2. TOTAL ENGINEERING MANPOWER REQUIREMENTS FOR NEE, FTFB AND AFTF AS A FUNCTION OF TIME.

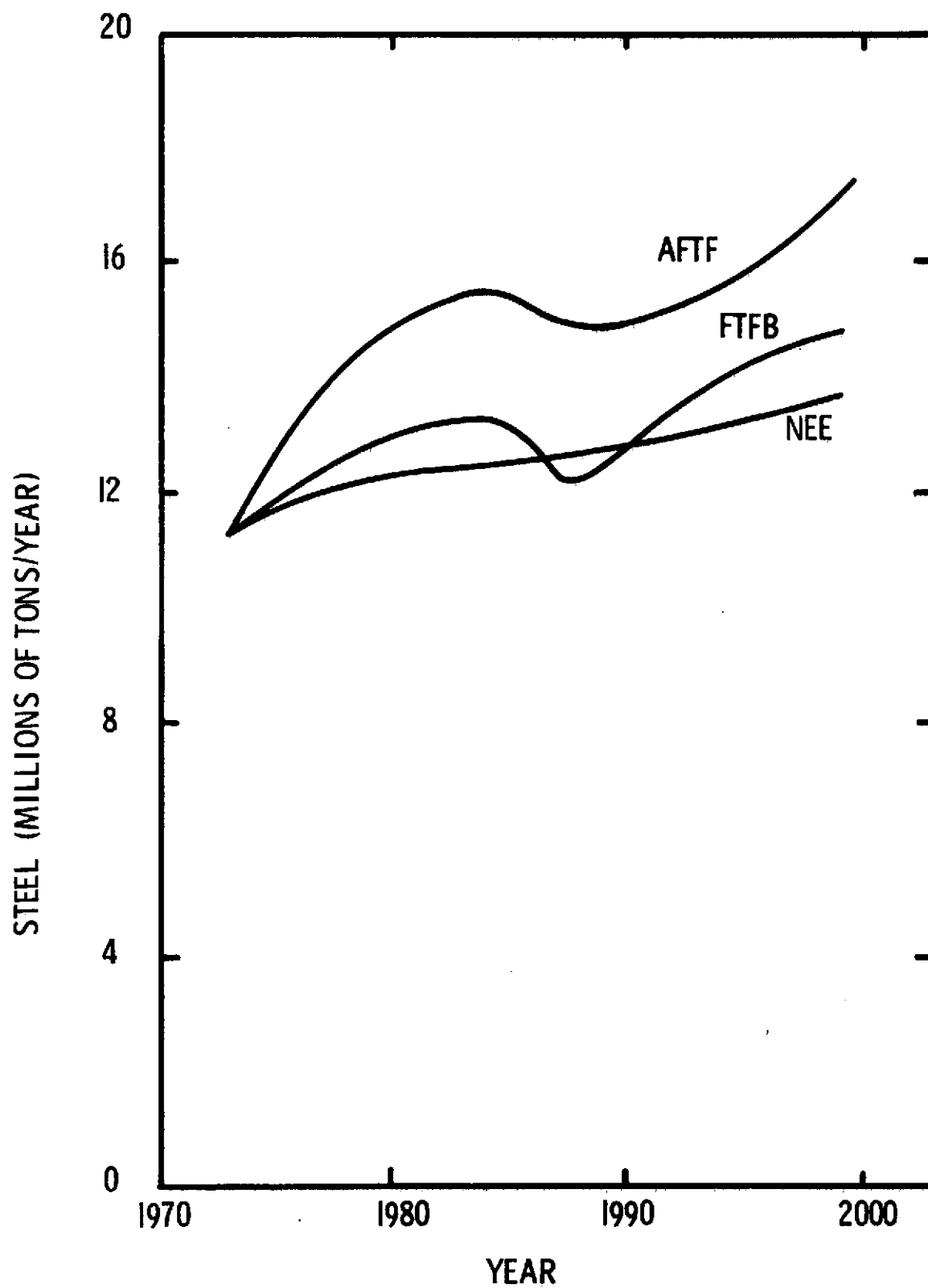


FIGURE 3. ADJUSTED TOTAL STEEL REQUIREMENTS FOR NEE, FTFB, AND AFTF AS A FUNCTION OF TIME.

1980 are 180 million tons of raw steel capacity and 133 million tons of mill products [Hein-74]. If a linear growth of the steel industry is assumed, 272 million tons of raw steel capacity and 201 million tons of mill products will result at 2000. If the energy industry uses the same share of mill products that it currently does, a supply of 20 million tons would be available - a value in excess of any demand for the scenario. No finer resolution of steel was attempted. Classes of steel were not defined or quantified and the steel in boilers, turbines, etc. were not included.

No problems are foreseen in this material area except for a possible steel mill product-mix imbalance. The study did not detail this problem.

Cement requirements were tabulated in MEGASTAR. Other materials were not tabulated either because of insufficient data or because small amounts were called for and no potential shortage or bottlenecks were foreseen. As an example of insufficient data, it was very difficult to assess copper requirements in the various sizements of the energy industry. But copper production is currently lagging behind demand and future shortages are certainly possible. In addition, it is anticipated that some items necessary to energy growth will be difficult to obtain. These include but are not limited to:

Turbo - generator sets  
Reactor pressure vessels  
Pumps and motors  
Cooling towers

Heat Exchangers  
Compressors  
Transformers and switchgear  
Heavy equipment

#### °Capital

The capital requirements for the three scenarios are shown in Figure 4. Because of its higher energy supply requirements, NEE is by far the most capital intensive of the three. AFTF requires more capital expenditure per year until 1997 than FTFB, reflecting the need to overbuild the energy supply system in order to obtain zero energy growth at 2000. The AFTF capital requirement does not go to zero at 2000 because replacement and energy supply changes are continuing. Gas and oil resource development also demands capital.

The capital available for investment in the U.S. is 18% of the GNP [Felix-72]. The 1973 U.S. GNP was 1025 billion dollars, resulting in 184.5 billion dollars of capital investment. The 1973 energy sector investment was 30 billion dollars, which meant 16% of investment capital was directed toward the energy sector. If the investment ratio and energy sector investment ratio of 0.18 and 0.16 are assumed constant 2000, and the GNP is anticipated to be 2635 billion dollars [Felix-72], 76 billion dollars would be available for energy sector investment. This value is smaller than the projected NEE need for 87 billion dollars, but is clearly greater than the FTFB and AFTF capital needs. It appears that some concern for financing NEE exists if these ratios remain constant.

The FTFB and AFTF scenarios depend heavily on energy conservation. No attempt has been made to quantify the capital needs to effect conservation since it is viewed as an end use. The difference between capital available at 2000 and the needs of FTFB or AFTF must be sufficient to contain conservation capital demands, or else neither FTFB or AFTF will be economically viable. A detailed assessment of conservation costs should be made.

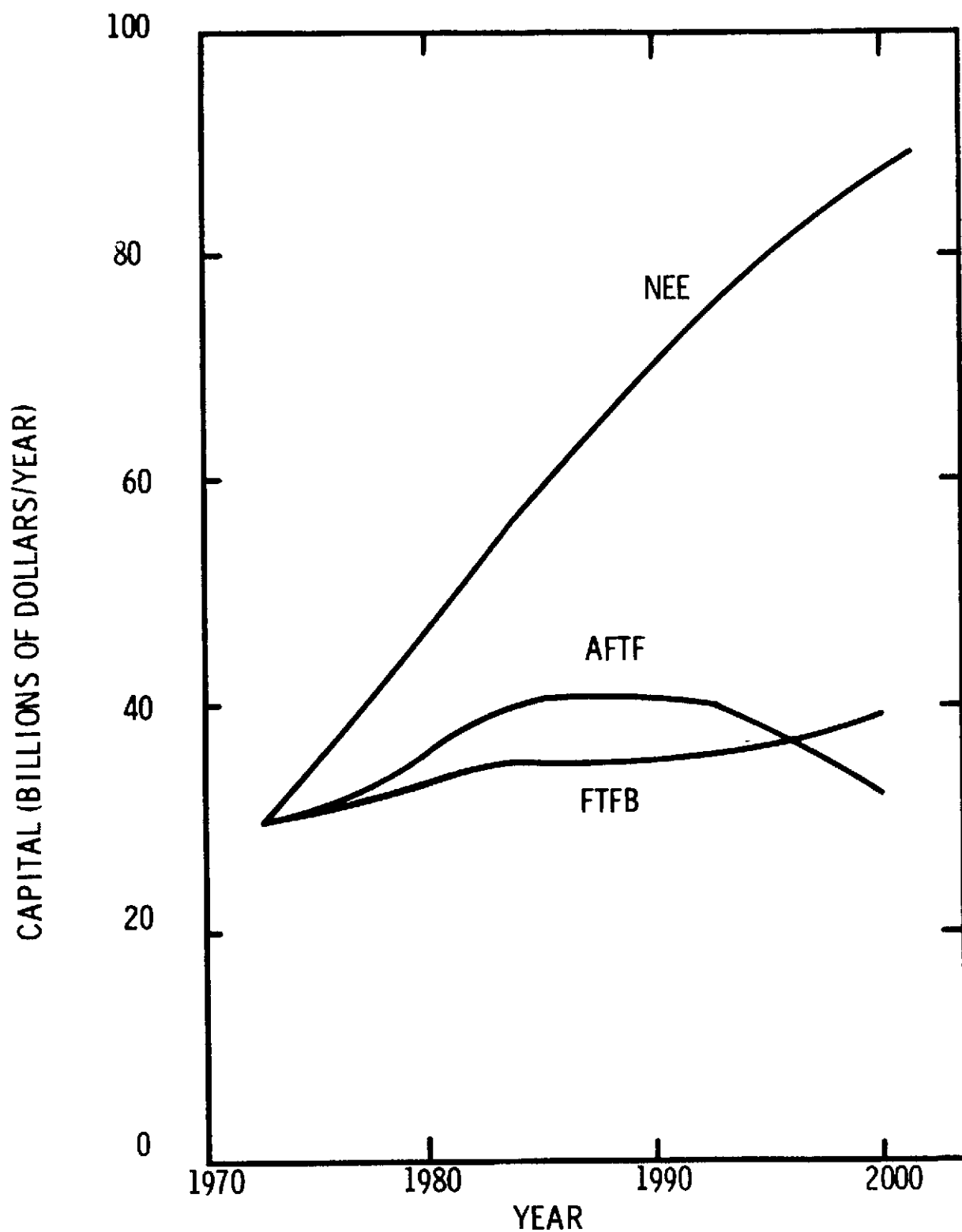


FIGURE 4 ADJUSTED TOTAL CAPITAL REQUIREMENTS FOR NEE, FTFB AND AFTF AS FUNCTION OF TIME

If FTFB or AFTF were followed, it is doubtful that 76 billion dollars would be available for investment. The reason is that historically capital investment is related to GNP and GNP is related to energy level, but under FTFB or AFTF the relation between economic growth and energy growth would be changed. The lower energy levels may imply lower available capital investment, but no detailed assessment of these interactions has been made. However, it still appears that FTFB and AFTF can be accomplished since the 1973 investment of 30 billion dollars should be able to grow to the required 40 billion dollars per year.

## 8. SCENARIO - DEPENDENT INSIGHTS

### °Fuel Roles

For all three scenarios, an assumption has been made that significant new domestic oil and gas reserves will be found including offshore reserves. The difficulties of actually finding these reserves are indicated below.

In 1970, record additions to oil reserves were found totalling 74 Quads. Of this, 56 Quads were found on the north slope of Alaska at Prudhoe Bay. Excluding Alaska, approximately 18 Quads were added to reserves.

In 1985-2000, 30 Quads must be added to reserves each year to satisfy the FTFB scenario.

In 1975-1985, 25 Quads/year of oil reserves must be found to satisfy the NEE scenario.

Domestic oil reserves discoveries have been approximately 18 Quads/year in recent years and have been declining.

Clearly, the energy future of the United States is dependent on domestic oil discoveries if the United States is to avoid dependence on imports.

All three scenarios are heavily dependent on development and utilization of coal. In all three scenarios, nuclear energy must provide an increasingly large segment of the U.S. energy requirements. Breeder reactor technology and commercialization are not required for the technical fix scenarios. The necessity for breeder commercialization for the NEE scenario depends on the future price of uranium fuels; but it is at present difficult to imagine PWR or BWR reactor construction in the 1990's based on present uranium resources. Nuclear power plants have an expected life of 40 years, and utilities will not build reactors without assured fuel supplies.



TABLE III. INCREASES IN TOTAL FUEL USE FOR SCENARIOS  
(PERCENT INCREASE COMPARED TO 1973 VALUES)

Scenario	Coal		Oil & Gas <sup>a</sup>		Nuclear	
	1985	2000	1985	2000	1985	2000
NEE	209%	500%	4%	4%	700%	4600%
FTFB	67%	127%	8%	24%	480%	820%
AFTF	92%	127%	33%	24%	250%	820%

a. Includes total Quads for oil and gas, regardless of source.

### °Conservation

The energy savings attributed to "painless" conservation, i.e., improvements in end-use efficiency of energy, in the FTFB and the AFTF were assumed to be the same. Some of the same kinds of savings were used in the NEE scenario. Some of the methods used for savings are the same; for example, use of insulation and heat pumps in buildings and homes, and transfer of hauling via trucks to rail, are present in all scenarios considered. On the other hand, FTFB and AFTF attributes a savings of 9.3 Quads to the use of 25 mi/gal cars by the year 2000, whereas NEE obtains 8 Quads of savings by converting 60 percent of the cars to electric. Obviously, the same kinds of actions that are necessary to implement change to 25 mi/gal cars would be necessary for electric cars. However, an additional consideration in the case of electric cars is the engineering development needed.

During the course of this study, it became obvious that "painless" conservation is not necessarily painless. It is possible at a price, but the consequences of conservation actions should be thoroughly assessed. Most of the impacts of implementation of these energy-savings practices were found to be in the social/political area.

### °Factors Not Considered

The scenarios studied herein have assumed that U.S. society essentially continues as it is now in areas other than technology. Time beyond the year 2000 was not considered. Interactions outside the U.S. were not considered with the exception of oil imports which were assumed to be decreasing. Paths were energy-time curves, one for each source, and were constructed from smooth (no path or slope discontinuities) curves drawn through the present with its 4 percent slope, and intermediate 1985 point given by the scenario, and the future at 2000 with the slope defined by the scenario. Values at five year intervals were then interpolated. A more logical procedure would be to identify the energy consumers and portray energy as a requirement of the consumers' needs and activities. This, however, requires a broad statistical base and models of energy consumption. Such a procedure might identify areas of energy use in society where consumption is inadequate to meet human needs and point out directions for future policy.

A societal disruption can lead to a discontinuity in the path and would invalidate the above assumptions. War or famine would be examples of such disruptions. A decrease in oil prices by OPEC in response to U.S. resource development is another. Some observations that may indicate potential disruptions in society are:

The world may be close to the population limits of growth and food and water shortages already exist in some areas (India and Africa).

The disparity in consumption of the world's goods between the Third World and the developed nations is increasing.

About 10 percent of the people of the U.S. live in poverty, i.e., in families of greater than two with less than \$3000/year income.

Progress is continually needed on limiting nuclear weapons and controlling nuclear materials.

Automation has the potential to achieve more leisure for society, or alternatively, to cause severe unemployment.

Once such a disruption does occur, review using a systems approach scheme would help judge whether the future need be modified, or the path adjusted to get back on an alternate path to the future.

#### °Questionable Assumptions

Within the scenarios are implicit assumptions that are subject to debate. The NEE and FTFB scenarios assume historical growth in energy demand, but the FTFB uses efficiency of end use conservation to cut the historical energy growth rate in half. Historical growth for the war-time type economy of the 1960's has been extrapolated into peacetime. Inflation also compounds the problem. Historical growth assumes inelasticity between price and demand and is mainly a consequence of cheap energy. The degree to which rising prices will reduce demand is unknown.

The NEE assumes electrification of society with a rate of nuclear growth that is very large. Already current AEC projections are below those of the NEE scenario for 1980 and 1985. The gas industry predicts gas production will rise if price deregulation occurs. The Prudhoe Bay find is expected to double domestic reserves if negotiations lead to a favorable decision for a gas pipeline through Canada. A huge distribution system of gas pipelines exist. Even if low estimates of gas resources prove correct the existence of this distribution system may slow down electrification. The need for water may require widespread desalination of saltwater. Nuclear reactor or solar heat to desalinate water, in conjunction with water dissociation to store and transport energy as hydrogen would allow the gas pipelines to continue to be used.

The source mix path that characterizes each of the scenarios is limited to known source technologies. Flexibility to make use of more efficient end uses of energy is built in through what are called technical fixes. That same flexibility would be useful for sources. As time and research brings increased understanding of social and environmental costs, modifications will occur in the source mix. Ultimately fossil power and nuclear fission power are interim measures in progress to renewable resources. Path flexibility with target dates to bring in renewable source technologies would be desirable.

## 9. SCENARIO - INDEPENDENT INSIGHTS

Certain areas of concern are common to any discussion of the U.S. energy future. In this section, several are singled out as especially important in the judgment of the MEGASTAR group.

### °Electrification

A common feature of the three scenarios examined in this study is the trend toward increased use of electricity. This trend is not unrealistic since electrification has been increasing by 7 percent annually in recent years, double the overall energy growth rate. Indeed, the current uncertainty about domestic petroleum and natural gas reserves and incomplete development of processes to produce synthetic oil and gas from coal, makes electrification a logical goal. Nuclear fission and direct coal use are best suited for generation of electricity as well as fusion and central station solar. This indicates that electricity, however generated, will probably have a larger role in the future energy system.

### °Oil and Gas Reserves

Considerable uncertainty exists regarding the undiscovered oil and gas which remains in the U.S. Better knowledge of the oil and gas resource base would make decisions regarding energy planning and policy much easier. Determining the onshore resource base cannot be accomplished in a short period, but it appears that the offshore areas should be explored relatively quickly under Federal Government sponsorship. This should be seriously considered, but it could have adverse consequences.

### °Capital Problems

The trend in segments of the energy industry toward an increasing share of the capital needs of the industry is currently of concern. The electric utilities, for example, are growing at an annual rate of 7 percent, but their capital needs are growing at 14 percent. This may reflect, in part, an attempt to expand the rate base. However, many utilities are experiencing a decrease in financial ratings with subsequent worsening of their financial condition. This problem must be addressed now to assure a strong utility industry.

The scenario-related capital problems of the energy industry have been discussed previously and under the assumptions stated there, the total capital requirements for the energy sector do not appear to be critical except possibly for the NEE. This assumes, however, that the energy industry will be as successful in the future in competing in the capital market as it has in the past as well as ignoring the capital problems of some sectors of the energy industry, e.g., the utilities.

### °Environmental Problems

The energy industry must continue to provide U.S. energy needs without unacceptable environmental damage. One of the costs of preventing unacceptable environmental damage is energy for powering pollution control equipment and to make up losses due to additional inefficiencies that may be caused by the operation of such equipment. If the industry is able to meet environmental protection standards and to include the cost of the required equipment in the price of their product, no problems are foreseen. The problem is not energy vs. environment but in assuring that a sufficient part of the total energy produced is available for solving environmental problems.

### °Manpower

If historical growth continues, shortages of engineering manpower will occur unless a larger percentage of the engineering population is involved in the energy sector or the total engineering population increases. Similarly, shortages of skilled craftsmen are anticipated. A potential solution to this problem is the establishment of training schools by industry itself in the construction areas. In the U.S. manpower is allocated by the market. Government could intervene to assure manpower supplies, but it would be a radical departure from present political philosophy.

### °Conservation as a Resource

Conservation is not "painless" but may represent a new opportunity for technology to realize this quasi resource. Some examples include:

Low grade Heat Both scenarios examined indicate great potential for conserving energy by investing in equipment to utilize more of the available energy in a fuel or to make up for conversion losses in electrical generation. The technology of heat transfer, heat pumps, heat transport, and insulation are examples.

Materials Material shortages will require the development of materials substitutes. Development of novel and special purpose materials has advanced in recent years and will need to continue if energy goals are to be met.

Fabrication New fabrication techniques will be necessary to handle new materials and to provide increased energy efficiency in industrial processes.

Control Systems Many opportunities for improving control systems should emerge. Sophistication of control systems must increase because of the increasing complexity of tasks. An example would be the control problems in a dual solar-fossil home. Every aspect of control systems present opportunities for innovation: sensors, transducers, signal and control paths, decision electronics, telemetry, alarms, recorders, and actuators and indicators.

Technology for Conservation The need for increased efficiency in energy use and new technology, e.g., electric cars, should produce a new growth industry to supply these requirements. Such an industry should also have a good potential for technology export to the rest of the world.

### °Social/Political Consequences

Independent of the scenarios examined, however, is the implied need for long-range planning. Although long range policies are developed and adhered to over many decades, there is no general acceptance in this country of long-range planning in which general guidelines are formulated for action, then reduced to the selection of an action option, which is then translated into action.

It would appear that scenario "builders" assume the presence of, or the establishment of, institutions that are both competent and ready to perform long-range planning in an environment of broad social consensus. However, it is not apparent that institutions competent at long-range planning exist or are in the formation stage; nor can it be shown that a consensus exists that is supportive of a planning institution's function. The whole problem of the role of government in planning and in the carrying out of planning is one that is common to all of the scenarios and overshadows other social and political problems connected with energy. It basically hinges on the conflict between the good and rights of the individual vs. the good and rights of society and so goes far beyond the energy area. This group has no new insights on this problem, but does suggest that one of the things that is needed to help resolve this problem is a careful and thorough assessment of the costs and benefits that would accompany an expanded governmental role in the planning process.

### °Unresolved Energy Problems

#### Energy Market and Government Intervention:

The market system as it exists in the United States cannot be characterized as a purely competitive system. The energy market is no exception to this because of the oil oligopoly and regulated utilities, both gas and electric. Price fixing, by means of public service commission rate structures, and administered prices, that are common in the oil industry, are not features of a competitive market.

The market system, as it has traditionally existed in the U.S., is also not a full social cost market. The price that consumers pay does not often reflect the cost of polluting air, land, and water. A full social cost market system is unlikely to evolve in the U.S. without government intervention in the market or an unprecedented demand by citizens on industry to factor in social costs. In either case the result would be further movement away from a pure competitive market.

Government intervention in the market is nothing new; the oldest such intervention is the import duty, which provided some degree of protection for fledgling industry as well as revenue for the government. In the energy area, government intervention has also influenced the market; oil import quotas, which protected domestic producers from competition with cheap foreign oil, are an excellent example of intervention in the energy market place. There is some disagreement as to how much influence the Federal Government should exert in the energy market. However, as is pointed out above, the government is already involved and even a decision to withdraw its influence from the market would have significant consequences.

If a Federal energy policy is formulated, it is certain that it will guide government action with respect to the energy market. It is sometimes asserted that the government could not influence the energy market to the degree necessary without exercising unacceptable dictatorial control. However, a careful examination of some of the normal options open to government reveals many possible choices which are acceptable and reasonable; some of these options are already being exercised.

Past government intervention in the energy market has been a fact-of-life for the energy industry, particularly in production, and to a lesser

extent in consumption. However, in looking to the future one can ask, what will be the role of government in the energy market?

### Zero Energy Growth:

The finiteness of the earth's resource base, the finite capacity of the world for absorbing environmental damages, the limited share of the presently available energy now held by less developed countries, the eventual saturation of per capita demand--all these have been advanced by the Energy Policy Project [Ford-74] as reasons for ZEG. Related reasons for ultimately adopting ZEG as national energy policy are increasing competition for land and water between energy uses and other uses, such as food production, and possible decreased industrial demand for energy due to shortages or recycling of raw materials. ZEG may for some of these reasons eventually be adopted out of necessity or society may voluntarily choose to institute it sooner.

### The Relationship of the U.S. to the Rest of the World:

Although the focus of this report has been on the U.S. energy system, it is recognized that the U.S., in energy as in other areas, does not exist alone. The only external interaction that was explicitly taken into account in this report was the importation of oil and gas. One of the important problems with long-term, international, social and political implications that was not considered in this report is the problem of the world-wide distribution of energy supplies.

It is unlikely that the rest of the world will continue to tolerate the wide differences in per capita energy consumption that now exist. This will mean increased competition and therefore, prices for international energy resources and the materials necessary to utilize those resources, such as energy consumption have a considerable potential for the generation of international problems, e.g., the Arab oil embargo. This is a problem which requires careful examination in the near future.

## 10. SUMMARY

### °Energy a Requirement

There is an energy eilemma. Energy supply and utilization is but one requirement among a number of interrelated requirements of a viable nation as illustrated in Figure 5. The dilemma exists because, the planning of other national requirements has assumed that the historically readily available surplus of energy in convenient form at decreasing real prices would continue. For some years the needs of the energy system itself have been deemphasized.

### °Systems Approach to Energy Planning

The use of scenarios in planning energy development is part of the systems approach in which each alternative for energy resources, power generation, conversion, and end use is examined as part of the subsystem embodied in the national system. It should be emphasized that an energy scenario is visualized as a projection into the future on the basis of current data and not a rigid path to be followed year by year. The use of

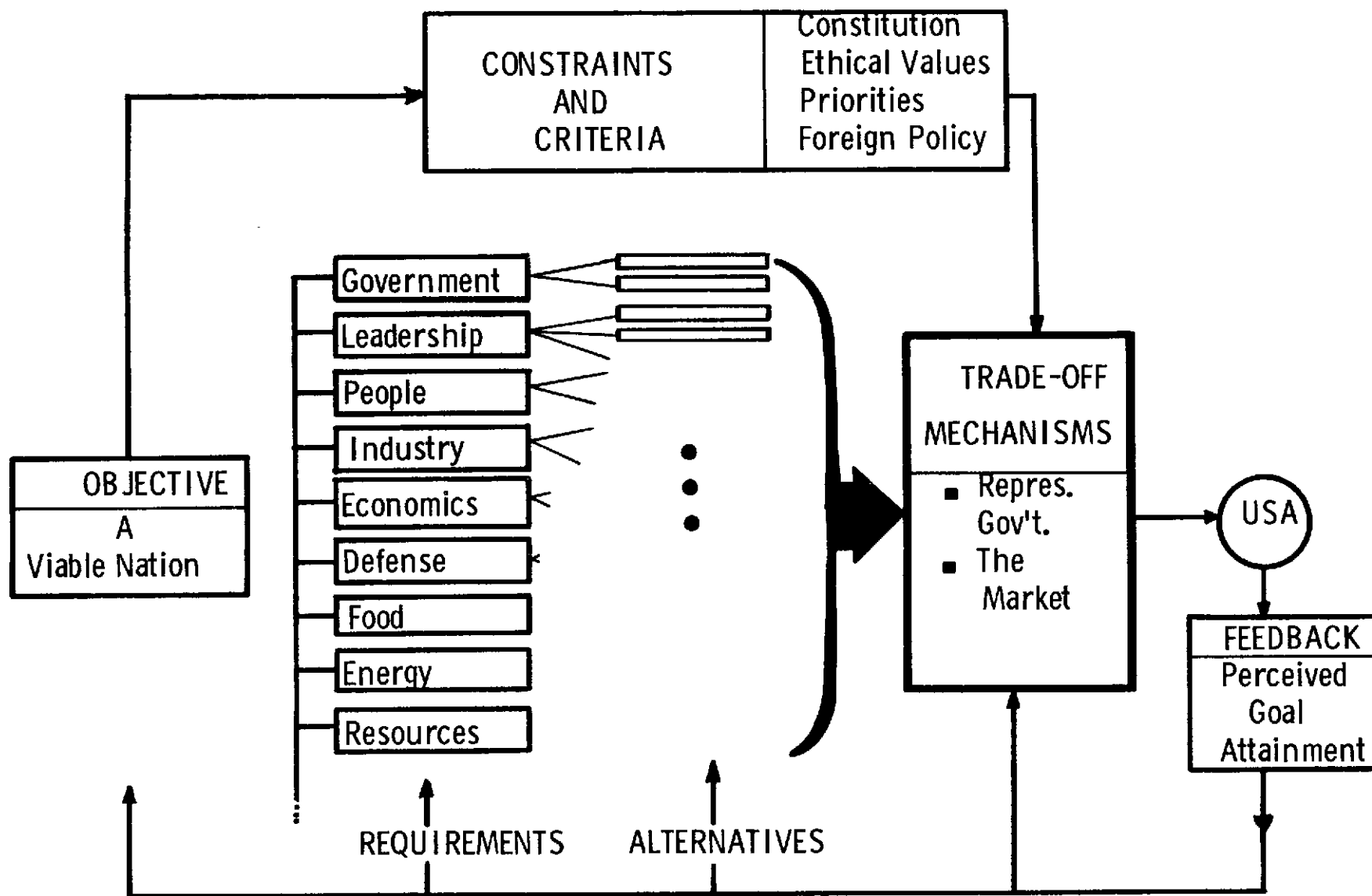


FIGURE 5 SYSTEMS APPROACH DISPLAY OF THE U.S. SHOWING THE NATIONAL ENERGY SUB SYSTEM AS A BASIC REQUIREMENT FOR A VIABLE NATION.



scenarios with the systems approach permits a projection of requirements and an assessment of the impacts of these requirements for various energy futures. This in turn allows the decision maker to choose an energy future that is most consistent with the constraints and criteria established by the nation. Energy planning is not static, but a process which should be reviewed periodically to take into account changing objectives and criteria.

There are a number of interrelated decisions that must be made in sequence if the potential of a future systems, such as fusion or solar, is to be realized. Each future system has a chain of decisions into the future with the initial point now or in the near future. Describing futures in scenarios gives the decision maker an opportunity to assess the consequences of various decisions in light of the constraints and criteria. Of course, ultimate decisions on future energy systems can only be made after the feasibility of all the concepts have been proven.

MEGASTAR is meant to provide an outline for understanding the meaning of energy growth and to present a methodology for examining energy futures to demonstrate that delineation of the dilemma into a debatable problem is possible.

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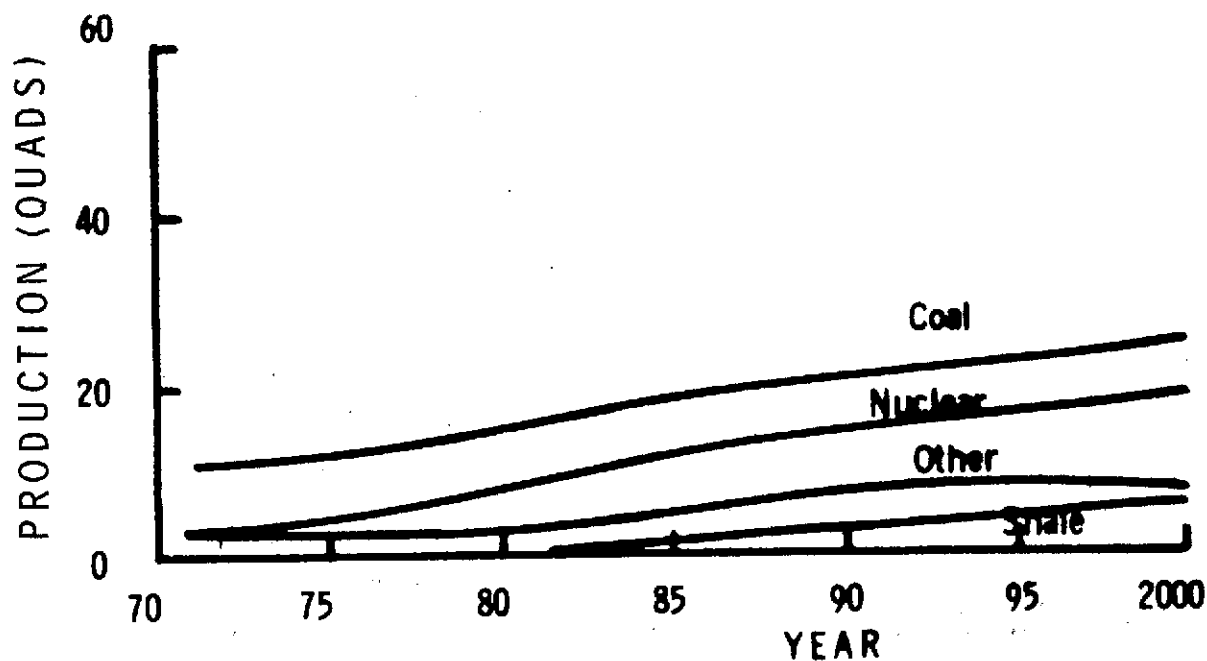
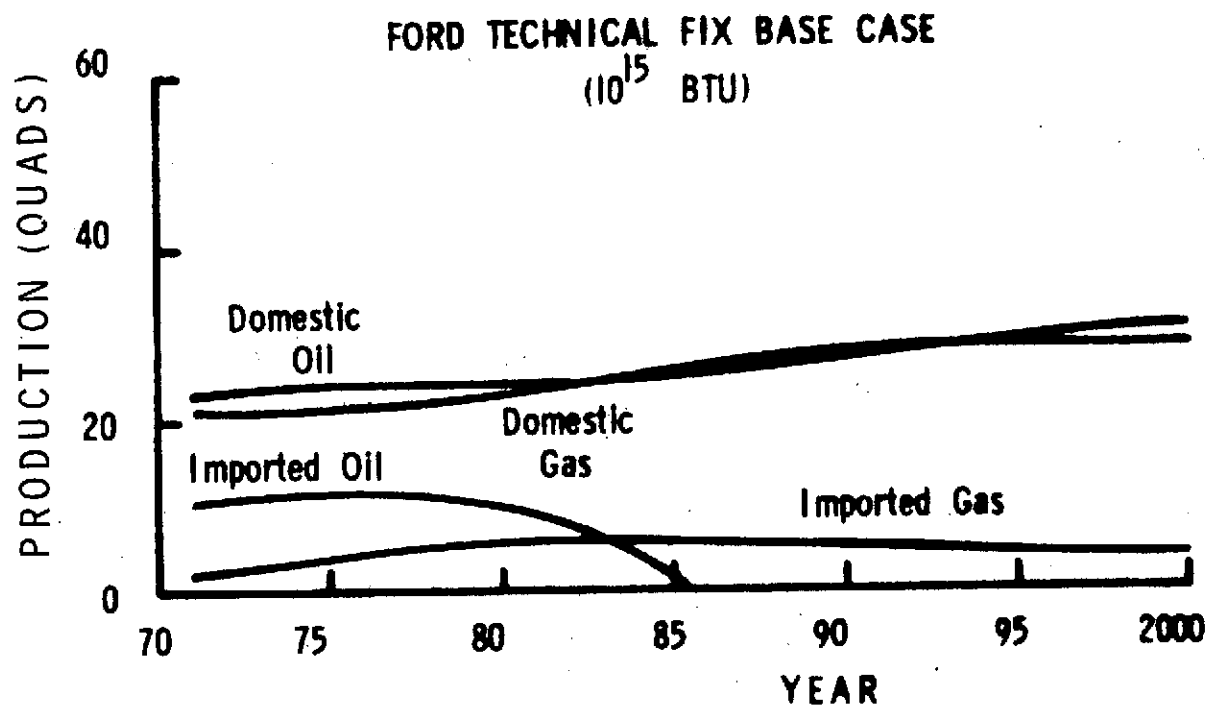


FIGURE 7-2 FORD TECHNICAL FIX BASE CASE - PRIMARY FUEL PRODUCTION

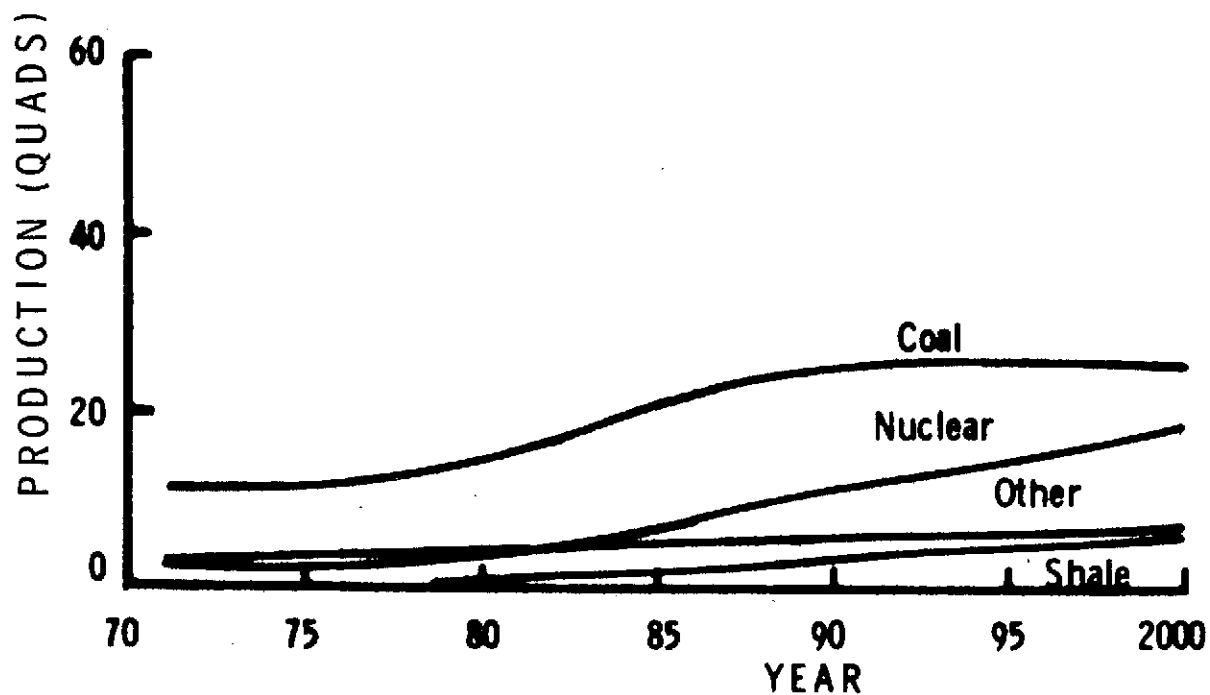
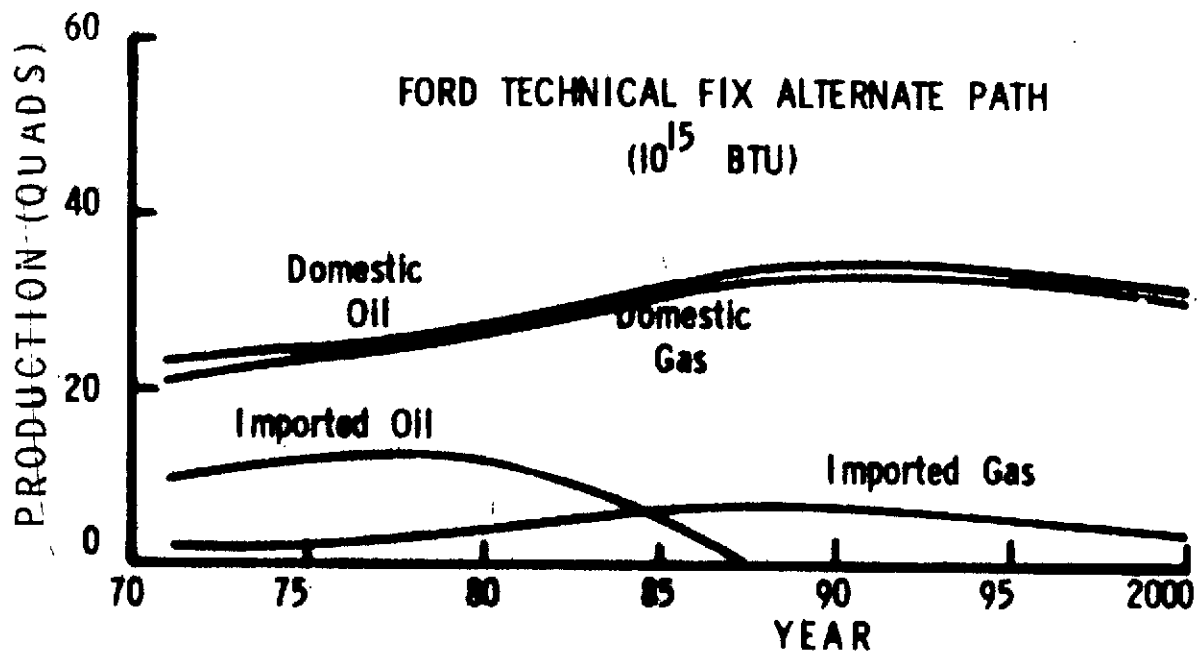


FIGURE 7-1 FORD TECHNICAL FIX ALTERNATE PATH -  
PRIMARY FUEL PRODUCTION [Ford-74]

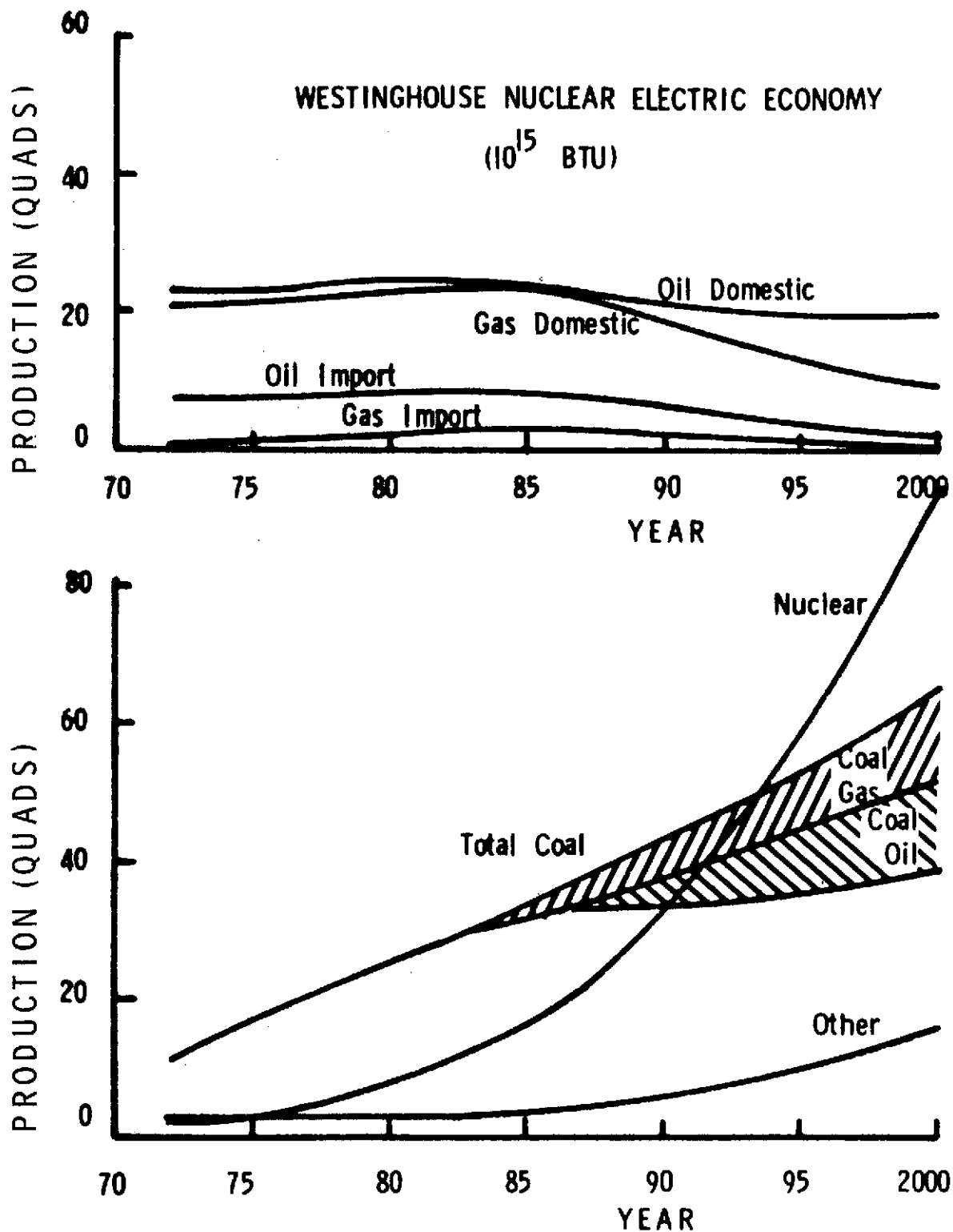


FIGURE 7-3 WESTINGHOUSE NUCLEAR ELECTRIC ECONOMY -  
PRIMARY FUEL PRODUCTION [Ross-73]

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